

S/PRTS

DT04 Rec'd PCT/PTO 12 OCT 2004

CIRCULATING SUB

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2

3 The present invention relates to hydraulically operated
4 downhole tools and in particular, though not exclusively,
5 to a control sub to provide selective control of a
6 hydraulically operated expander tool for tubulars.

7

8 It is known in the art to utilise the pressure of fluid
9 pumped through a work string in a well bore to control a
10 hydraulically activated tool in the well bore. For
11 instance, when expanding tubulars such as slotted, screen
12 or solid pipe a rotary expander may be used. These
13 expanders have a cone head with an outer diameter greater
14 than the diameter of the tubular. On the tool are
15 arranged hydraulically operated rollers. When mounted on
16 the end of a work string and inserted into a tubular,
17 hydraulic pressure introduced to the expander tool will
18 force the cone through the tubular and with the aid of
19 the rollers the tubular will be expanded to the diameter
20 of the expander tool.

21

22 The hydraulic pressure to operate these tools is
23 typically supplied from the surface of the well bore by

1 pumps. Due to the distances of travel to the location of
2 the expander tool it is difficult to control the
3 operation of the expander tool and, in particular, to
4 provide a constant pressure to give a uniform control and
5 therefore expansion of the tubular in the well bore. It
6 is also difficult to start and/or stop the expander tool
7 at desired locations in the well bore.

8
9 It has been recognised that being able to control the
10 flow of hydraulic fluid adjacent a hydraulically operated
11 downhole tool would be advantageous. US 5,392,862
12 describes a drilling mud flow control sub that provides
13 the necessary fluid flow and pressure to activate an
14 expanding remedial tool such as an underreamer, section
15 mill or other cutting tool. The sub consists of a
16 cylindrical sub assembly housing forming a first upstream
17 end and a second downstream end. The housing is
18 threadably connected between a drill string at its first
19 upstream end and a tool at its downstream end.
20 Intermediate the upstream and downstream ends is located
21 a drop ball seat so that insertion of a drop ball will
22 prevent hydraulic fluid flow to the tool. A rupture disc
23 is affixed to a hole formed in the control sub wall
24 normal to the sub axis, above the drop ball seat, so that
25 when obstructed fluid is shunted from sub.

26
27 This flow control sub provides means to terminate fluid
28 flow to the tools hydraulically operating mechanism while
29 allowing fluid circulation through the sub when the tool
30 is 'deactivated' while 'tripping' and/or rotating the
31 drill string. However a major disadvantage of this tool
32 is in the single function operation i.e. in turning the
33 hydraulic mechanism off. There is no selective control of

1 the tool. Additionally when hydraulic fluid is applied to
2 the tool through the sub the pressure of this fluid can
3 only be controlled from the surface as with the prior art
4 systems. Further a disadvantage is in the length of time
5 taken for the drop ball to reach the seat and the
6 associated difficulties if the single ball does not
7 locate correctly in the seat.

8
9 It is an object of at least one embodiment of the present
10 invention to provide a control sub for use with a
11 hydraulically operated downhole tool which allows the
12 tool to be operated in selective on and off
13 configurations.

14
15 It is a further object of at least one embodiment of the
16 present invention to provide a control sub for use with a
17 hydraulically operated downhole tool which allows control
18 of the hydraulic pressure delivered to the tool.

19
20 It is a yet further object of at least one embodiment of
21 the present invention to provide a control sub for use
22 with a hydraulically operated downhole tool which allows
23 selective control of fluid circulation when the tool is
24 run in or tripped from the well.

25
26 It is a still further object of the present invention to
27 provide a method of controlling hydraulic pressure to a
28 hydraulically operated downhole tool in a well bore.

29
30 According to a first aspect of the present invention
31 there is provided a control sub for use with a
32 hydraulically operated downhole tool, comprising a
33 tubular assembly having a through passage between an

1 inlet and a first outlet, the inlet being adapted for
2 connection on a workstring, the first outlet being
3 adapted for connection to a hydraulically operated
4 downhole tool, one or more radial outlets extending
5 generally transversely of the tubular assembly, an
6 obturating member moveable between a first position
7 permitting fluid flow through the one or more radial
8 outlets and a second position closing the one or more
9 radial outlets, wherein the obturating member is moved
10 from the first position to the second position by a
11 compressive force applied from the tool.
12

13 It will be appreciated that release of the compressive
14 force will open the one or more radial outlets and thus
15 by varying the compressive force applied from the tool
16 the amount of fluid circulated radially out of the sub
17 can be controlled. Preferably the cross-sectional area of
18 the first outlet is greater than the cross-sectional area
19 of the second outlet. By varying the circulation of fluid
20 radially from the sub the fluid exiting the sub through
21 the first outlet can be varied. This fluid exiting the
22 first outlet controls the hydraulic pressure applied to
23 the tool and therefore the operation of the tool.
24

25 Preferably the compressive force occurs from the downhole
26 tool remaining static relative to movement of the
27 workstring and the control sub. Thus the control sub acts
28 in a similar manner to weight set tools but provides
29 control as weight is set.
30

31 Preferably the tubular assembly comprises an inner sleeve
32 and an outer sleeve, sealingly engaged to each other.

33 Preferably the outer sleeve is adapted to connect to the

1 work string and the inner sleeve is adapted to connect to
2 the tool. More preferably the inner and outer sleeves
3 include mutually engageable faces so that the sleeves may
4 be axially slideable in relation to each other over a
5 fixed distance.

6

7 Preferably also the obturating member is a sleeve.
8 Advantageously the sleeve is coupled to the inner sleeve
9 of the tubular assembly. Preferably the obturating
10 member is also axially slideable within the tubular
11 assembly.

12

13 Preferably the one or more radial ports are located on
14 the outer sleeve. Advantageously matching radial ports
15 are located on the obturating member such that under
16 compression each set of radial ports align to allow fluid
17 to flow radially from the sub.

18

19 Preferably an outer surface of the inner sleeve includes
20 a portion having a polygonal cross-section. Preferably
21 also an inner surface of the outer sleeve has a matching
22 polygonal cross-section. These matching sections ensure
23 that when the work string is rotated the sub is rotated
24 and with it the hydraulically operated tool. More
25 preferably the polygonal cross section is a hex cross-
26 section.

27

28 Preferably also the sub includes an indexing mechanism.
29 The indexing mechanism may comprise mutually engageable
30 formations on the inner and outer sleeves. Preferably the
31 engagement formations comprise a member and a recess in
32 which the member may be engaged. The member may comprise
33 a pin and the recess may comprise a slot. Preferably, one

1 of the member and the pin is mounted on the outer sleeve
2 and the other is mounted on the inner sleeve. Typically
3 the slot extends circumferentially around the respective
4 sleeve and the pin may move circumferentially with
5 respect to the slot.

6

7 Preferably the slot and/or pin is configured such that
8 the pin and slot move in only one direction to each other
9 when engaged and operated.

10

11 Preferably also the slot includes one or more
12 longitudinal profiles as offshoots from the
13 circumferential path. When the pin is located in such a
14 profile, the sleeves may move relative to each other to
15 effect the relocation of the obturating member from one
16 position to another.

17

18 According to a second aspect of the present invention
19 there is provided a method of controlling a hydraulically
20 operated downhole tool in a well bore, the method
21 comprising the steps:

22

23 (a) mounting above the tool on a work string a control
24 sub, the sub including a first outlet to the tool and
25 one or more radial outlets through which fluid within
26 the work string will flow when not obstructed by an
27 obturating member, the obturating member being moveable
28 under a compressive force from the tool;

29

30 (b) running the tool into a well bore and locating the
31 tool on a formation in the well bore;

32

33 (c) compressing the control sub by setting down weight

1 on the tool;

2

3 (d) using the compressive force to move the obturating
4 member and thereby control the fluid flow through the
5 radial outlets, regulating the fluid pressure from the
6 first outlet to hydraulically control the tool.

7

8 Preferably the method includes the step of running the
9 tool in the well bore with the radial outlets in an open
10 position and circulating fluid within the well bore.

11

12 Preferably the method includes the step of indexing the
13 sleeves with respect to each other to move a pin in a
14 sleeve within a recess of the other sleeve. Further steps
15 may therefore include locating the pin in a position
16 wherein the compressive force may be released and the
17 radial ports may selectively be in an open or closed
18 position.

19

20 Preferably also the method may include the steps of
21 picking up and setting down the weight of the string
22 repeatedly to cycle opening and closing of the radial
23 outlets and thus provide a selective continuous 'on' and
24 'off' operation of the tool.

25

26 Embodiments of the present invention will now be
27 described, by way of example only, with reference to the
28 accompanying drawings of which:

29

30 Figures 1(a) to (d) are a series of part cross-sectional
31 schematic views of a control sub, according to an
32 embodiment of the present invention, in a work string
33 with an expander tool illustrating the operating

1 positions of the control sub during expansion of a pipe;
2 and
3

4 Figure 2 is an illustration of an indexing mechanism
5 showing the outer surface of an inner sleeve and, in
6 cross-section, the outer sleeve of a control sub
7 according to a further embodiment of the present
8 invention.
9

10 Reference is initially made to Figures 1(a) to (d) of the
11 drawings which illustrates a control sub, generally
12 indicated by Reference Numeral 10 according to an
13 embodiment of the present invention, in a work string 12
14 with an expander tool 14 illustrating the operating
15 positions of the control sub 10 during expansion of a
16 pipe 16 within a casing 18 of a well bore.
17

18 With specific reference to Figure 1(a), control sub 10
19 comprises a tubular body 20 having an outer sleeve 22 and
20 an inner sleeve 24. Outer sleeve 22 is of two-part
21 construction, having an upper portion 26 and a lower
22 portion 28. Upper portion 26 includes a threadable
23 portion 30 for connection of the sub 10 to a work string
24 12. Upper portion 26 includes four apertures 32
25 circumferentially arranged around the sleeve 22 to
26 provide access through the sleeve 22. Lower portion 28
27 is threadably attached to upper portion 26. Lower
28 portion 28 has an inner surface 34, which is hexagonal in
29 cross-section. When threaded together the upper 26 and
30 lower 28 portions of the outer sleeve 22 provide a lip 36
31 whose purpose will be described hereinafter.
32

1 Inner sleeve 24 includes a central bore 35 through which
2 fluid may pass through the control sub 10. Inner sleeve
3 24 has an outer surface 38 having a hexagonal cross-
4 section to match the inner surface 34 of the outer sleeve
5 22. Inner sleeve 24 further provides a threadable
6 connection 40 at the base of the sub 10 for connection to
7 an adapter 42 for an expander tool 14. Beside the
8 threadable connection 40 is located a stop 44.

9
10 The upper end of inner sleeve 22 is threadably connected
11 to an obturating sleeve 48. Obturating sleeve 48 is
12 located within the inner bore 35 of the control sub 10.
13 Obturating member 48 includes a matching set of apertures
14 50 to those apertures 32 in the outer sleeve 22. It will
15 be appreciated by those skilled in the art that the size
16 and dimensions of the apertures 50 could be varied to
17 provide a flow profile to regulate flow through the
18 apertures 32 of the outer sleeve 22. Further at a lower
19 end of sleeve 48 is located a lip 46.

20
21 In use, the control sub 10 is mounted at the end of a
22 work string 12 by threadable connection 30. An expander
23 tool 14 is located onto the control sub via a threadable
24 connection 40 with an optional adapter 42. As seen in
25 Figure 1(a), when mounted the lips 36, 46 of the outer
26 sleeve 22 and obturating sleeve 48 respectively abut so
27 that the inner sleeve 24 and obturating sleeve 48 are
28 supported from the outer sleeve 24. In this first
29 position of the obturating sleeve 48 the apertures 50 and
30 32 are aligned to provide a radial port for the expulsion
31 of fluid radially from the sub 10 towards the casing 18.
32 This is the configuration chosen for running the work
33 string into the well and thus fluid can circulate from

1 the sub via the inner bore 35 and the radial port
2 provided by the apertures 32, 50.

3

4 Reference is now made to Figure 1(b) of the drawings
5 wherein the work string has been run in the well bore
6 through the casing 18 and the expander tool 14 has now
7 located on a pipe 16 which requires to be expanded
8 radially. When the expander tool 14 reaches the pipe,
9 the expander tool will be stopped and the weight of the
10 string will bear down upon the tool such that the tool 14
11 provides a compressive force onto the sub 10. The
12 compression force will move the inner sleeve 24 relative
13 to the outer sleeve 22, such that the inner sleeve 24
14 remains static and the outer sleeve 22 is shifted
15 relatively downwards. This shift of the sleeves 22 and
16 24 provides an apparent shift of the obturating sleeve 48
17 such that the apertures 32, 50 are now mis-aligned.
18 Fluid flow is now prevented from exiting the tool
19 radially through the apertures 32, 50. Further fluid is
20 prevented from escaping between the sleeves 22, 24 by
21 virtue of the o-rings 52, 54 located on either side of
22 the aperture 50 of the obturating sleeve 48.

23

24 Reference is now made to Figure 1(c) of the drawings
25 wherein the sub 10 is held in compression. The expander
26 tool 14 has been pressured up and no pumping of fluid
27 through the inner bore 35 is required to maintain the
28 expander tool in the actuated position unless a bleed is
29 located in the expander tool 14. Pipe 16 is expanded by
30 virtue of a cone 56 of the tool entering the pipe 16 and
31 forcing the pipe to expand to a diameter equal to the
32 actuated expander tool 14. Expander tool 14 is operated
33 from a constant pressure of fluid delivered through the

1 inner bore 35. Pipe 16 can become sealingly engaged to
2 the casing in this operation. Alternatively, there may
3 be annulus remaining between pipe 16 and casing 18.

4
5 It will be appreciated by those skilled in the art that
6 any type of hydraulically operated expander tool could be
7 used in this configuration and thus, a full description
8 of an expander tool is absent so as not to limit the
9 present invention.

10
11 As the expander tool expands the pipe it maintains a
12 compressive force on the sub 10 so that the ports 32, 50
13 remain mis-aligned for the pressure to be maintained
14 constantly through the inner bore 35. In a preferred
15 embodiment of the present invention there is located
16 within the bore 35 a sensor 58. Sensor 58 is a downhole
17 pressure memory gauge which monitors the pressure of the
18 hydraulic fluid through the bore 35. This can be used to
19 determine that a constant hydraulic pressure has been
20 exerted on the expander tool to monitor the expansion of
21 the pipe 16. It will further be appreciated that if the
22 pressure within the bore 35 requires to be adjusted,
23 weight can be released from the string 12 thereby
24 reducing the compressive force from the expander tool 14
25 such that some alignment of the apertures 32, 50 occurs
26 and a small radial expulsion of fluid from the sub 10 may
27 occur to control the pressure within the bore 35.

28
29 When the pipe 16 is fully expanded in the casing 18 the
30 expander tool 14 can be pulled from the well by
31 "tripping" the sub 10 on the work string 12 from the
32 casing 18. As the expander tool 14 does not abut the
33 surface of the pipe 16 when the pipe 16 is expanded, as

1 shown in Figure 1(d), there is no weight bearing facility
2 for the expander tool 14 and thus a compressive force on
3 the sub 10 is released. When the compressive force is
4 released, the inner sleeve 24 drops in relation to the
5 outer sleeve 22 and thereby causes the obturating sleeve
6 48 to relocate to the first position wherein the
7 apertures 32 and 50 are now realigned to provide a radial
8 port for hydraulic fluid within the inner bore 35 to pass
9 from the sub 10 into the annulus created between the sub
10 10 and the casing 18. Thus, as the tool 14 is pulled out
11 of the hole, fluid can circulate within the well bore.
12 Control sub 10 is thus in tension during this operation.
13

14 Reference is now made to Figure 2 of the drawings, which
15 illustrates an additional feature of the sub 10, provided
16 in a further embodiment of the present invention. Like
17 parts to those of Figure 1 have been given the same
18 Reference Numeral but are now suffixed 'a'.
19

20 In this embodiment the sub 10 is provided within an
21 indexing mechanism generally indicated by Reference
22 Numeral 60. Indexing mechanism 60 comprises an index
23 sleeve 62 located on the inner sleeve 24 on the sub 10a.
24 On the outer surface 38a there is located a profile 64.
25 Profile 64 is a key providing a lower 66 circumferential
26 arrangement of v-grooves and on every second groove there
27 is located a longitudinal portion 68. On the outer
28 sleeve 22a there is located one or more index pins 70.
29 In the embodiment shown there is one index pin 70. Index
30 pin 70 is arranged to project towards the inner bore 35a
31 and locate within the profile 64. The pin 70 may move to
32 any position within the profile 64 as long as it remains

1 in the path provided around the lower profile 66 or is
2 located into one of the longitudinal portions 68.

3

4 In operation, a sub 10a including the index mechanism 60
5 would be run into a casing as described herein with
6 reference to Figure 1. When the tool has landed on a
7 formation in well bore, the pin 70, originally located in
8 the longitudinal portion 68, will be driven along the
9 slot and into the circumferential portion 66.

10

11 When the pin 70 is located at a top 72 of the
12 longitudinal portion 68, the radial ports 32a, 50a are
13 aligned and fluid may circulate from the sub 10a as
14 described herein before.

15

16 When the index pin 70 is located within the
17 circumferential portion 66, the ports 32a, 50a are closed
18 as described herein with reference to Figure 1(b) and
19 1(c). As the circumferential slot 66 includes a number of
20 v-grooves, each v-groove provides a cavity 74 into which
21 the pin 70 can locate and be held relative to the sleeve
22 62. When the pin 70 is located in the cavity 74, the sub
23 10a can be picked up on the string 12a and thus the
24 expander tool can be tripped from the well bore with the
25 ports 32a and 50a in a closed position. By compression
26 and release of the sub in a reciprocating action, the
27 index pin 70 can be moved around the circumferential
28 profile 66 and thereby the position of the ports 32a,
29 50a, can be selected to provide controlled operation of
30 the tool 14a.

31

32 In the embodiment shown in Figure 2, the sub 10a may be
33 picked up while the ports 32a, 50a remain closed and only

1 on every second time the tool is picked up will the ports
2 become open by virtue of the pin moving from the cavity
3 74 into the slot 68.

4
5 A principal advantage of the present invention is that it
6 provides a control sub for a hydraulically operated
7 downhole tool, which controls the hydraulic pressure to
8 the tool adjacent to the sub. A further advantage of the
9 present invention is that it provides selective operation
10 of a hydraulically operated downhole tool while the tool
11 is in the well bore.

12
13 By use of an indexing mechanism, a further advantage of
14 the present invention is that it ensures that pressure is
15 maintained upon the expander tool without the risk of the
16 radial ports opening and thus the expander tool can be
17 reciprocated within a well bore without loss of hydraulic
18 pressure upon the expander tool.

19
20 Modifications may be made to the invention herein
21 described without departing from the scope thereof. For
22 example, it will be appreciated that any number of
23 apertures can be arranged to provide radial expulsion of
24 the fluid for circulation from the sub. Additionally,
25 these ports may be arranged to expel fluid in a direction
26 substantially upwards or downwards in relation to the
27 casing. Further, it will be appreciated that the control
28 sub of the present invention could be used in a well
29 bore, which is vertical, inclined or horizontal.